Study of cold fusion reactions with the BGS

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Cold fusion reactions with heavy ion projectiles and lead or bismuth targets produce compound nuclei with rather low excitation energies (< 30 MeV). As a group, cold fusion reactions produce isotopes of the heavy elements ($Z \geq 102$) that are neutron deficient and exhibit both alpha and spontaneous fission (SF) decay properties. These reactions are important, as the cross sections are relatively high compared with actinide-target-based "hot fusion" reactions producing similar isotopes. These higher cross sections, coupled with high separation efficiencies in the Berkeley Gas-filled Separator (BGS), allow the study of cold fusion reaction mechanisms. By developing an understanding of cold fusion reaction mechanisms, predictions can be made that best estimate the production cross sections of the heaviest elements.

Several reactions have been examined during the past year using lead and bismuth targets and the BGS at the 88-Inch Cyclotron: ^{208}Pb(^{48}Ca,xn)$^{256-x}$No, ^{208}Pb(^{50}Ti,xn)$^{258-x}$Rf, ^{209}Bi(^{50}Ti,xn)$^{259-x}$Db, ^{208}Pb(^{51}V,2n)^{257}Db, and ^{209}Bi(^{51}V,2n)^{258}Sg. In each of these experiments, the projectiles were accelerated by the 88-Inch Cyclotron to energies leading to 12-26 MeV excitation energies at the center of the target. These excitation energies correspond to the maxima of the 1n- and 2n-exit channels. The projectiles fused with lead and bismuth targets of approximately 500 μg/cm^2 thickness. Based on calculations and simulations, as well as comparisons with similar experimental data, the separation efficiency in the BGS for these reactions is 45 ± 5%. In most of the reactions, a parallel plate avalanche counter was used to discriminate between signals originating from the focal plane detector and signals from particles passing through the BGS. Isotope identification was made by searching for, correlations between the evaporation residue (EVR) implantations and alpha-decay or SF in the focal plane detector.

A total of 32 cross sections were obtained for the 5 reactions examined. Experimental half-lives of the 12 isotopes produced were obtained. All of these cross sections and half-lives are available in Reference [1].

From these experiments several important conclusions were drawn. First, the experimental results for the ^{208}Pb(^{48}Ca,xn)$^{256-x}$No reaction are comparable to similar experimental results obtained at other institutions showing that the BGS is extremely effective at separating EVRs from scattered beam and transfer products. Second, when comparing the cross sections for the ^{209}Bi(^{50}Ti,2n)^{257}Db and ^{208}Pb(^{51}V,2n)^{257}Db reactions (leading to the same compound nucleus), the bismuth-target cross sections appear larger than those with lead targets. The ^{208}Pb(^{50}Ti,2n)^{256}Rf reaction cross sections are larger the two ^{257}Db cross sections. Finally, the ^{209}Bi(^{51}V,2n)^{258}Sg cross section is depressed significantly (by a factor of 1000) when compared to the ^{208}Pb(^{50}Ti,2n)^{256}Rf reaction.

These experiments form the beginning of an understanding of the cold fusion production mechanisms that can be used in the future production of the heaviest elements. Future work should be directed at obtaining complete excitation functions for the 1n- and 2n-exit channels for all of the reactions mentioned as well as extending these experiments to the production of larger Z isotopes.

Footnotes and References

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